

Final Report on NASA Grant NAGW-1480

X-ray Observations of Late-type Stars Using the ROSAT All-Sky Survey

University of Colorado Proposal No. 0688.08.0635B and renewals

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4P*Introduction*

NASA grant number NAGW-1480 funded a project which was somewhat unconventional. The *ROSAT* mission made the first X-ray survey of the entire sky using an imaging detector. Although *ROSAT* is a joint NASA/German project and involves direct American participation during its second phase of pointed observations, the all-sky survey remains the sole property of the German investigators. NASA grant NAGW-1480 represented the first use of *ROSAT* data analysis funds to support direct American participation in the *ROSAT* all-sky survey.

The project involved a collaborative agreement between the Joint Institute for Laboratory Astrophysics (JILA) and the Max-Planck-Institut für Extraterrestrische Physik (MPE) where JILA supplied MPE with a post-doctoral research associate (Fleming) with experience in the field of stellar (coronal) X-ray emission to work within their *ROSAT* group. In return, members of the cool star research group at JILA were given the opportunity to collaborate on projects involving *ROSAT* all-sky survey data. Both sides have benefited (and still benefit) from this arrangement since MPE suffers from a shortage of researchers who are interested in X-ray emission from "normal" stars and white dwarfs. MPE has also drawn upon Dr. Fleming's experience in optical identification of

X-ray sources from the *Einstein* Extended Medium Sensitivity Survey in planning their own identification strategies for the *ROSAT* all-sky survey. The JILA cool stars group has benefited, since access to all-sky survey data has expanded the scope of their already extensive research programs involving multiwavelength observations of late-type stars.

ROSAT was successfully launched on 1 June 1990 and conducted the bulk of the survey from 30 July 1990 to 25 January 1991. Data gaps in the survey have subsequently been made up. At the time of this writing (February 1992), the survey data have been processed once with the Standard Analysis Software System (SASS). A second processing will soon begin with improvements made to the SASS to correct errors and bugs found while carrying out scientific projects with data from the first processing.

We outline below the major research activities of Dr. Fleming over the past year (detailed accounts of his activities during the first two years of this grant can be found in the first-year and second-year status reports on this grant.) Regarding the three specific projects which were proposed in the original proposal, two of them (White Dwarfs and Late M Dwarfs) are near completion. The results are described in two conference proceedings which are appended to this report. Expanded versions of these papers will soon be submitted to the *Astrophysical Journal* (late M dwarfs) and *Monthly Notices* (white dwarfs). Very little work has yet been done on the L_X vs. age project yet but Dr. Fleming, who will be staying on at MPE for another year as a Max Planck stipendiat, hopes to start this project in the near future.

Research

Dr. Fleming, together with the MPE science team, has spent most of the last year verifying and analyzing the PSPC data output by the SASS, as well as making in-flight calibrations of the PSPC. With such a large amount of data as in the *ROSAT* all-sky survey, one must rely on automatic methods for detecting sources, measuring count rates, etc. Therefore, it is essential to find all possible errors in the reduction programs so that one can have confidence in the results.

Dr. Fleming, together with Dr. Steve Snowden, have particularly addressed inconsistencies in spectral analysis of the lowest energy channels of the PSPC detector which

occurred in fitting atmospheric models to white dwarf calibration sources such as HZ 43. This work has resulted in the release of new a detector response matrix and effective areas for the PSPC by the ROSAT Data Center. Dr. Fleming also, in conjunction with Dr. G. Hasinger and S. Schaedt, developed the first methods for computing corrections (e.g. vignetting, window support shadowing) for ROSAT survey light curves.

The scientific highlights of research conducted under this grant are as follows:

- No evidence found for a coronal dividing line in the H-R diagram at the cool end of the main sequence. Dwarfs later than spectral type M5 are just as efficient in creating coronae as early M dwarfs. L_X/L_{bol} remains constant for saturated M dwarfs of all types. (Fleming, Giampapa, Schmitt, and Bookbinder 1991)
- Discovery of the fact that most DA white dwarfs are NOT X-ray or EUV sources as was previously thought. Apparently, there are appreciable abundances of metals in white dwarf atmospheres which can only be detected in the soft X-ray regime. (Barstow, Fleming, Diamond, and Finley 1991)
- Discovery of another Sirius system in the solar neighborhood: β Crateris. It seems that A star plus white dwarf systems are common. (Fleming, Schmitt, Barstow, and Mittaz 1991)
- Failure to detect a corona around the archetypal red giant Arcturus. Any coronal flux must be at least four orders of magnitude lower than solar values. (Ayres, Fleming, and Schmitt 1991)
- Discovery of coronae around Pop II stars. The Pop II analogs to the RS CVn binaries still retain active chromospheres and coronae after 8 billion years. (Pasquini, Fleming, Spite, and Spite 1991).

Publications Resulting from Research Conducted Between 9/90 and 2/92

Fleming, T.A., Schmitt, J.H.M.M., Barstow, M.A., and Mittaz, J.P.D. (1991). " β Crateris: Another Sirius System in the Solar Neighbourhood," *Astron. Ap. Lett.*, **246**, L47.

Ayres, T.R., Fleming, T.A., and Schmitt, J.H.M.M. (1991). "Digging in the Coronal

Graveyard: A ROSAT Observation of the Red Giant Arcturus," *Ap. J.*, **376**, L45.

Pasquini, L., Fleming, T.A., Spite, F., and Spite, M. (1991). "Detection of Strong Chromospheric and Coronal Activity in Pop II Binaries," *Astron. Ap. Lett.*, **249**, L23.

Fleming, T.A. (1991). "X-ray Observations of Cool Stars with ROSAT," in *Proceedings of the MINI-Workshop on Coronae and Winds in Late-type Stars*, ed. E. Leer and P. Maltby (University of Oslo), p. 91.

Fleming, T.A., Giampapa, M.S., Schmitt, J.H.M.M., and Bookbinder, J.A. (1991). "The Nature of the Dynamo at the End of the Main Sequence: A ROSAT Survey of the Late M Dwarfs," in *Seventh Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun*, ed. M.S. Giampapa and J.A. Bookbinder, in press.

Barstow, M.A., Fleming, T.A., Diamond, C.J., and Finley, D.S. (1991). "ROSAT Observations of White Dwarfs," in *Symposium on Hot Stars*, ed. Uni. Kiel, in press.

Publications Resulting from Work Done Between 9/88 and 8/90

Fleming, T.A., Gioia, I.M., and Maccacaro, T. (1989). "X-ray Selected Candidates for the RS CVn and W UMa Classes of Binary Stars," *A.J.*, **98**, 692.

Fleming, T.A., and Giampapa, M.S. (1989). "A Search for Chromospheres at Faint Magnitudes," *Ap. J.*, **346**, 299.

Liebert, J., Green, R.F., Bond, H.E., Holberg, J.B., Wesemael, F., Fleming, T.A., and Kidder, K. (1989). "A Compact Planetary Nebula Around the Hot White Dwarf EGB 6/PG 0950+139," *Ap. J.*, **346**, 251.